



Dentin bonding in the root canal

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Introduction

The term *monoblock* has recently appeared in the endodontic literature. Literally, the word means one mass or obstruction, but was previously used in medicine and dentistry to describe single unit components or appliances. In applying adhesive dental technology to root canals, Teixeira et al. introduced the term monoblock to describe resin sealant in the root canal that bonds to primer and a resin core without the gaps commonly found in gutta-percha obturations. Theoretically, an impervious seal would be created from the orifice to the foramen of a root canal and eliminate the pathway for bacterial leakage to the periradicular space.¹ This report reviews the rationale for applying dentin bonding technology to the root canal and provides an update on the application of dental adhesive technology to radicular dentin.

The role of bacteria in endodontics

Bacteria are responsible for pulpal and periradicular infection. Re-infection of the root canal space will occur with traditional obturation materials if there is lack of a coronal seal.² The number of bacteria found in a root canal infection can vary between 10^2 and 10^8 .³ Root canal infections are polymicrobial and new endodontic pathogens are continuously being reported. Techniques to eliminate these microbes through irrigation and debridement are limited by the complexity of canal morphology. Better methods of entombing remaining pathogens and blocking new microbes from reentry may increase favorable outcomes of non-surgical treatment.

Dentin bonding

The basic principle of adhesion in dentistry involves removal of calcium phosphate from tooth substrate, exposing microporosities followed by infiltration and polymerization of the resin.⁴ The resultant area of micromechanical interlocking is called the "hybrid layer".⁵ Although infiltration and hybridization are required for all bonding, glass-ionomers are thought to have a twofold adhesion that involves the exchange of tooth material for synthetic resin and a true primary chemical bonding. An ionic bond between the carboxyl groups of polyalkenoic acid and the calcium of synthetic hydroxyapatite (HA) has been demonstrated.⁵

The conventional *etch and rinse* approach for resin involves two or three steps. The acid etchant, or *conditioner*, is followed by an adhesion promoter, the *primer*, before the actual bonding agent, or *adhesive resin*, is applied. The etching step commonly uses a 30-40% phosphoric-acid gel that selectively dissolves HA crystals. The priming step is critical and can be achieved by air-drying acid etched enamel or dentin if a water/ethanol based adhesive is used.⁵ If an acetone-based adhesive is used, wet bonding is mandatory.⁶ The adhesive resin step involves *in situ* polymerization of resin that envelops the individually exposed HA crystals. However, in dentin the acid treatment exposes collagen nearly devoid of HA. Thus, the primary bonding mechanism to dentin is diffusion-based and relies on the infiltration of resin in an exposed collagen scaffold.⁴ True chemical bonding to dentin is unlikely because the functional groups

of the monomers have a weak affinity for the HA-depleted collagen. It is thought that this weak interaction is responsible for the *nanoleakage* phenomenon.⁷

Self-etch systems are popular because eliminating etch and rinse makes them user-friendly and reduces application time. Recent expert opinions published in an ADA Professional Product Review suggest these systems are technique sensitive because it is difficult to dry the adhesive film on the tooth when using a single bottle system.⁸ Self-etching systems are one or two-steps subdivided into strong and mild adhesives. Strong self-etches have a pH ≤ 1 . In dentin bonding, nearly all HA is dissolved and collagen is exposed. The resulting bond is diffusion-based, like etch and rinse. Mild self-etch systems have a pH near 2 and demineralize only 1 μ m of dentin. Although the resulting hybrid layer is thinner than in strong self-etch or etch and rinse systems, the surface demineralization is partial and some HA remains attached to the collagen. Preservation of HA with the hybrid layer may allow for some chemical bonding. Disadvantages of the self-etch approach include unknown effects of incorporating dissolved HA and smear layer within the bond, nanoleakage resulting from excess solvent that may affect polymerization of monomers, and a hydrophilic interface prone to hydrolytic degradation.^{4,7}

New obturation materials

Obturing root canals with resin has regained attention since 1976 when Hydron (poly [2-hydroxy ethyl methacrylate], or poly [HEMA]) was introduced as a replacement for gutta-percha. Following were attempts to use low viscosity unfilled BISGMA resins that proved unsuitable because they did not adapt to the canal wall and were difficult to remove in retreatment.⁹

Current endodontic materials using dentin bonding technology include resin obturators available as ISO standardized or non-standardized cones, pellets for use in thermoplastisized delivery systems, and resin-coated gutta-percha. Some popular brands include: Epiphany® (Pentron Clinical Technologies, LLC, Wallingford, CT), Real Seal® (SybronEndo, Orange, CA), Simplifill® (Lightspeed Technology Inc., San Antonio, TX), InnoEndo® (Heraeus Kulzer, Hanau, Germany), and EndoREZ® (Ultradent Products Inc., South Jordan, UT). It is beyond the scope of this paper to review all available products and the reader is referred to peer-reviewed dental journals for performance evidence. Common among systems is the manufacturer's recommendation to follow NaOCl canal irrigation with a final rinse of EDTA, then sterile water, saline or chlorhexidine. Sodium hypochlorite is a strong oxidative agent. As a final rinsing agent it would leave behind an oxygen-rich layer on the dentin surface, inhibiting the polymerization of resin and resulting in reduced bond strength.¹⁰

Currently, most systems utilize Resilon® as the obturating material and all can be categorized as self-etching. Resilon® is a synthetic polymer of polyester first adapted for endodontic use in the Epiphany® system in 2003. Its resin core is composed of polyester, difunctional methacrylate resin, bioactive glass and radiopaque fill-

ers. Resilon is non-toxic,¹¹ non-mutagenic, and biocompatible.¹² Epiphany[®] sealer is made primarily of methacrylate resins and Epiphany[®] primer is an acidic monomer solution in water with a MSDS reported pH of about 1.5. In theory, the primer bonds to dentin, the sealer bonds to primer, and Resilon[®] bonds to the sealer creating the monoblock. Epiphany SE[®], a self-etch sealer, is now available with no primer required.

Dentin bonding in the root canal

Dentin bonding in the root canal is complicated. Canal morphology and access to the apical third create obstacles to the uniform application of primer and adhesive. Once the primer is applied, the volatile carrier must be evaporated, but blowing compressed air into the root canal is not recommended for risk of air emphysema or embolism. If the acetone or the alcohol carrier is not completely removed, the bond is adversely affected.¹³ There are differences in the composition of dentinal tubules along the root canal and the ratio of dentinal tubules to inter-tubular dentin in coronal dentin is greater than in apical dentin. Also, the tubule diameter at the pulp chamber floor is smaller than in coronal dentin. The ability of a bonding agent to produce high shear bond strengths is dependent on these morphological characteristics of dentin.¹⁴

Since dentinal tubules in the apical third of the canal are unlikely to be penetrated, adhesive techniques rely on a hybrid layer to bond. Irregularities of dentinal tubules within the root canal may adversely affect the formation of a hybrid layer.^{15,16} Once bonding is complete, the hybrid layer is thinner in the apical areas.¹⁷ Inconsistent bonding in the apical third of the canal is common. Significant portions of canal walls are untouched by instrumentation during cleaning and shaping.¹⁸ And, dentin surfaces covered by debris and remnants may not sufficiently bond.

Cavity configuration factor, or C-factor, the ratio of bonded to unbonded resin surfaces, is often used as a measure of the cavity preparation geometry for bonding.¹⁹ As the ratio increases, polymerization contraction force can exceed the bond strength of dentin adhesives to dentin, resulting in gaps along surfaces with the weakest bonds. The greater the percentage of unbonded surface, the less stress on bonded surfaces during polymerization. Unbonded surfaces allow plastic deformation or flow within the resin mass during polymerization. In the root canal, this ratio may exceed >900:1 where every dentin wall has an opposing wall and there are minimal unbonded surfaces.²⁰ Tay et al. discovered that as the thickness of adhesive is reduced, the volumetric shrinkage is reduced, resulting in lower shrinkage stress (S-factor). Yet, an increase in C-factor overwhelms a decrease in S-factor. The interaction of C- and S-factors predicts that bonding of adhesive root-fillings to canals is unfavorable when compared with indirect intra-coronal restorations of similar resin film thicknesses.²⁰

Conclusion

In studies of resin-based obturation, conflicting data exists for bond strength, resistance to root fracture and enzymatic degradation. It is unknown whether resin will outperform gutta-percha unless in vivo comparative studies are completed. Today, bench-top studies suggest that current resin-based systems seal comparably to gutta-percha systems.

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